The Ohio State University
Campus as a Living Laboratory

Heffner Wetland Facility Roof Garden

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Executive Summary

We propose the construction of a roof garden on the Heffner Wetland Facility at the Wilma H. Schiermeier Olentangy River Wetland Research Park (ORWRP). This park in Columbus Ohio, managed by the Ohio State University School of Environment and Natural Resources, is dedicated to undergraduate, graduate, and professional level research and also serves as a venue for educating college students and the public. Issues and topics of focus in our project proposal that are aligned with the mission of the ORWRP include species conservation and diversity, sustainable design, rainwater management, student involvement, and student and public education.

Our roof garden is to be planted using native flowering species to provide nectar, pollen, and seeds for wildlife to enhance species diversity and populations at the ORWRP. The wildlife expected to benefit from this project includes both arthropod and vertebrate pollinators as well as seed eating perching birds. The roof garden is designed to provide similar environmental benefits to that of an upland prairie ecosystem including biodiversity conservation, rainwater absorption/use, and carbon sequestration as well as structural benefits to the Heffner Building such as temperature and noise insulation and a lengthened roof life due to protection from the sun's damaging rays. The design features lightweight and recycled materials that will be used to construct raised beds, pathways, an impermeable layer, and an observation deck. Additional habitat enhancement features will include bee boxes for native bees and bird baths as a source of water.

This project would require an improvement in roof strength, but the environmental and economic benefits as well as the visual and hands-on learning opportunities for visitors, public and student volunteers, student maintenance workers, research, and college classes would make the investment well worth it.

Introduction

A green roof is generally defined as a roof that provides environmental benefits to the structure and the surrounding community. Green roofs first originated in Northern Scandinavia in the form of grass covered cottages. They have since evolved into more modern designs involving alternative energy production, such as solar panels and wind turbines. Green roofs can be used for rainwater collection and to grow many different species of plants for multiple purposes. Another benefit is that they provide a barrier between the roof and the outside environment, improving insulation and offsetting energy expenses.

We propose to build a rooftop garden over the Heffner Wetland Building, located at the Scheirmeier Wetland Research Facility at the Ohio State University. This area offers a unique opportunity for the study of wetland ecosystems, promoting research in areas such as entomology, horticulture, and wildlife ecology. We hope to implement a garden of native nectar and seed producing vegetation that attracts local avian and invertebrate wildlife. Such an endeavor would promote the health and wellbeing of the wetland biosphere, as well as provide social, economic, and educational benefits.

The construction of a green roof garden over the Heffner Wetland facility would build awareness of the exclusive opportunity OSU students and faculty have to access a world-class research and Ramsar Wetland site. Not only would this create a lot of opportunities for greater forays into research, but also the chance for students to simply familiarize themselves with native flora and fauna of central Ohio. Free garden maintenance can be handled by student organizations, only further increasing student outreach programs. This green roof would increase insulation, something the Heffner Wetland building is severely lacking. This would decrease energy costs and reduce its carbon footprint, promoting the idea of OSU as a leader in sustainability efforts. A roof garden is also able to more efficiently collect grey water, again offsetting expenses for the Heffner Wetland building.

As a national leader in sustainable practices and conservation efforts, OSU is not only obligated to construct ecologically conscious buildings, but is also compelled to prepare its students to become the ecologically conscious citizens that go on to make the changes necessary to offset the current global environmental crisis. In order to create this generation of stakeholders, OSU must instill a value of ecosystem services into its students. We have come up with a plan to increase student interest and participation in the Wetlands area, as detailed later on in the paper, that we think is in alignment with this greater mission.

Roof Reinforcement

In its current state, the Heffner Wetland Building cannot support the weight of an extensive roof garden. After viewing structural plans for the Heffner building developed by Korda/Nemeth Engineering, Inc., it became clear that the Heffner building's roof can only support about 20 lbs./ft^2. After contacting the engineers, it was revealed that this 20 lbs./ft^2 of structural integrity is allocated for the live load of snow, rainwater, and high winds. In its current state, the Heffner Wetlands Building cannot support any additional weight. The average extensive roof garden weighs 30 lbs./ft^2, so the Heffner building certainly cannot support a roof garden (Alive Structures, n.d.). Although the Heffner Wetlands Building cannot hold a green roof in its current state, through roof reinforcement, it could be retrofitted with a lightweight green roof in the future.

Timeline

The Heffner Wetland Building must be structurally reinforced before it can be retrofitted with a roof garden. Structural reinforcement of a roof could entail additional support from a process called "welded roof support" or from adding more load bearing beams or walls to the Wetland Facility. The best time to reinforce the Heffner building roof would be when it is undergoing normal renovations. Due to normal wear and tear from weather, the average roof must undergo routine maintenance and normal renovations every ten to twenty years (Kosareo, 2007). Since the Heffner Wetland Building was built in 2001, it is reasonable to assume that the Heffner Wetlands Building will need to undergo routine maintenance on its roof within the next decade. The best time to reinforce the Heffner building would be when it is already undergoing normal renovations. By waiting until the Heffner building's roof is undergoing normal reconstruction, there will be a decrease in overall construction time and cost of roof reinforcements. This means that a roof garden on the Heffner Wetland building would not be installed for at least a decade, making this a long-term project plan.

Process of Reinforcement

To actually determine what structural reinforcements need to be done to the Heffner Wetland Building, an engineering firm would need to evaluate the structural integrity of the building in its current state. One firm has already evaluated the Heffner Wetland Building with the intent of determining if the building could hold a second story. This engineering firm determined that the wetlands building could not hold a second story. According to the its prints, the Heffner building can support almost no additional weight. In order to install an extensive vegetation layer and intensive raised beds on the wetlands building, the building would need to be able to hold an additional 20 – 60 lbs./ft^2. There are a few different ways of reinforcing the roof to ensure that a retrofitted roof garden would be safe and structurally sound. One common way of reinforcing a roof is to add systems called welded roof support. Welded roof support is a process in which "sheets of corrugated steel material are welded to purlins by elongated welds formed to resist rotation of the corrugated sheet in a horizontal plane… screws extend through sheets of rigid substrate and through rigids on the upper side of the corrugated shed to form a truss like structure extending generally parallel to the purlins" (Nunley, 1986). An engineering firm would need to be contracted to decide if welded roof support would provide an adequate amount of structural support to the wetlands building's roof. It is hard to estimate the cost of roof reinforcement without actually knowing what method of reinforcement will be required, but a rough estimate would be between $500 and $4,000 dollars.

To minimize the amount of reconstruction that must be done to the roof of the Heffner Wetland Facility, the roof garden would be designed with the intent of having one or two people on the rooftop at a time. This will greatly reduce the live load that the roof will need to hold. Only allowing one or two people onto the roof garden means that access to the roof must be monitored. The easiest way to restrict access to the roof would be to install a simple locking gate or door on the staircase leading up to the roof garden. This means that people will only be able to access the roof garden by retrieving a key from an employee at the Heffner Wetland Building. The main purpose of allowing limited access to the roof garden is so that one or two people may use the roof garden for research of native birds and insect species. A second story observation deck could be built directly adjacent to the Wetlands green roof in order to allow visitors of the Heffner Wetland Building to view the green roof without actually accessing the roof.

Our Design Plan

One of the most crucial components for the installation of a green roof is designing a plan that is feasible for the intended structure. A successful design has to be economically viable and account for the structure's ability to support additional weight. The infrastructure of the wetlands building has been analyzed to determine whether or not it could hold a second-story, and the analysis determined that a second-story would not be practical due to too much additional weight. Consequently, the installation of a green roof on the building would need to address this issue in a weight-conscious manner. Our group plans to address this problem by introducing innovative, lightweight substitutes for materials used in the construction of a green roof. Additionally, we plan to implement materials that can be recycled or reused to enhance the sustainable design of the roof.

A green roof's composition consists of six layers: a root barrier, a drainage layer, a filter layer, a water retention layer, a growing medium layer, and a vegetation layer (Bianchini, 2012). The root barrier is the lowest layer placed upon the roofing membrane and it is generally made from concrete. The purpose of this layer is to prevent leakage, prevent plant roots from growing into the building, and to serve as a waterproofing membrane. The next layer is the drainage layer, which is often made from polymer material, the purpose of which is to provide spacing between layers for water to freely flow off the roof. The third layer, the filter layer, is often made from thin polymeric layers and its function is to prevent particles from the upper layers from entering the drainage layer. These particles need to be filtered, because they can easily clog water in the drainage layer. The water retention layer is then placed above the filter layer to manage water runoff, as well as serve as a water storage layer for maintaining the moist composition of the growing medium. This layer is the most flexible in a design plan, because the layer's thickness is determined based on the amount of added water weight the structure can hold. The water retention layer is usually made from two substances, either mineral wool or polymeric fibers. The next layer, the growing medium layer, is often composed of soil and it is responsible for supplying the essential nutrients and water to allow the vegetation to thrive. Lastly, the vegetation layer consists of the green roof's plant life.

As stated above, all layers, aside from the growing medium and vegetation layers, of a green roof are often made from polymer material. The two most common types are polyethylene and polypropylene due to their ability to be lightweight, durable, inexpensive, and great insulators. A study conducted in 2011 by members of the University of British Columbia implemented a life-cycle analysis of these materials to determine how sustainable they are (Bianchini, 2012). To do this, the authors researched the amount of polluted emissions that resulted from the manufacturing process of the material and then compared the amount of emissions to the length it takes for a green roof to balance that amount of emitted pollution. They found that there are often two scenarios that occur when a green roof is constructed using polymers. In the first scenario, all layers of the roof are composed of non-recycled polymers. In the second scenario, the drainage and filter layers are composed of 40% recycled polypropylene and the water retention layer is 100% recycled polymeric material. The green roof with non-recycled polymers would take two-thirds of its lifespan to balance the amount of pollution, while the green roof with recycled polymers would only take one-third of its lifespan to balance the amount of pollution. This was based on the estimation that the green roof's lifespan would be 40 years. In conclusion, the study reported that installing green roofs with polymers, especially recycled polymers, is still beneficial, but it recommends the exploration of more sustainable options. Our proposal to install a green roof on the wetlands building calls for incorporating this recommendation to make the proposed green roof as sustainable as possible without adding additional weight.

To make this achievable, we recommend incorporating raised beds, thin green roof mats, a pathway, and an observation deck into the design plan. We recommend only implementing the green roof on the eastern section of the rooftop, because it possesses the most structural potential. The other section of the rooftop is mainly open ceiling space, and the retrofitting of this area to sustain the weight of a green roof would be much more costly. For the raised beds, we recommend placing these on the most structurally sound locations of the eastern-side of the roof. These would be the locations where support beams are already fixed to hold up the roof. We also recommend implementing thin green roof mats as a lightweight alternative to a normal, extensive green roof. These will cover the designated green roof portion of the rooftop for all areas not covered by the raised beds. Additionally, a pathway can be placed down the center of the roof. This path can be used to allow a small number of viewers or researchers onto the roof, or it can be exclusively used for maintenance. Lastly, we recommend building a wooden observation deck that will connect to the southern part of the building and allow visitors to view the green roof without compromising the fragile structure of the building. This deck will decrease the amount of structural renovation that will have to be done to the building and will ultimately decrease the cost of the project. A close-up of this design plan and all of its components can be seen in Figure 1 on the next page.

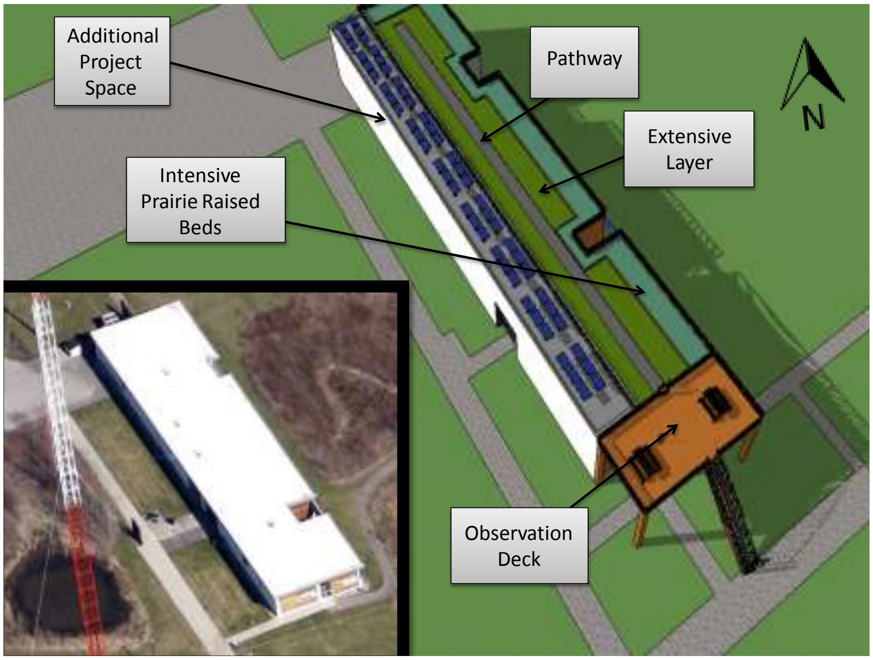

Figure 1: Model of Wetlands building with roof garden *(Google Maps, 2013).*

Raised Beds

The implemented raised beds will have the composition of an intensive roof top in order to support native prairie plants. These raised beds should be placed along the rows of horizontal support beams, which will make them run parallel to the width of the building. The overall length of the beds is not an issue as long as they do not overextend the well-structured half of the building. Our design for these raised beds recommends using recycled plastic lumber from high density polyethylene plastics for construction. We recommend designing beds on the interior of the roof to be 4 feet wide, while beds along the edge of the roof should be no more than 2.5 feet wide. Galvanized steel brackets and wood screws can be used for holding together the corners of the beds. Additionally, cross boards should be placed every ten feet to prevent the sides of the beds from bowing outward. All together, these beds will look like interconnected rectangles placed in a straight line.

To make these raised beds as light as possible, we recommend using a material called perlite, which is a white, volcanic ash substance that is used as a substitute for growing medium substrates, such as soil. The material is very lightweight compared to other substrates and it is also spacious (Appel, 2006). This helps create raised beds that are as light as possible, and it also improves the overall water irrigation of the rooftop. However, a drawback to using perlite is that it is so spacious that it does not retain the necessary amount of water and nutrients that plants within the raised beds would require. To solve this issue, perlite can be mixed with other substrates, such as peat moss, sand, or expanded shale (Ampin, 2010). Consequently, the raised beds are still at a lighter weight and the plants are given a compatible growing environment. The mixture of perlite and other growing media should be at least 12" deep in order to accommodate the intended vegetation.

Green Roof Mats

We also recommend adding thin, pre-vegetated green roofs mats. Some of the best choices available for maintaining a lightweight design are the green roof mat systems are called XF301 + 1FL and XF301 + 2FL, made by Xero Flor America (Xero Flor, 2013). This company is the exclusive distributor of Xero Flor green roof systems, which first originated in Germany over 40 years ago and have been implemented on thousands of rooftops, both retrofits and new construction. This is also the material that was used at the Ford Motor Company's River Rogue Plant, which possesses the largest green roof in the world (Ford Motor, n.d.). The XF301+1FL green roof system contains one layer of fleece, while the XF301+2FL system contains two layers of fleece. Both of these systems are extremely lightweight at 8-9 lbs./ft^2 and 9-11 lbs./sf^2 respectively when fully saturated (Xero Flor, 2013). Choosing the desired system will depend on the weight resistance of the building and the amount of water retention required at the Olentangy Wetlands area. It should be noted that the view of vegetation will be more prominent for the XF301+1FL system, because there is less material covering up the bases of the plants.

Applying green roof mats to the structure will allow the building to receive all the benefits of a green roof, such as insulation, without worrying about the weight issues of a normal, extensive green roof. It also helps reduce the amount of work required in the beginning installation, since the mats are already pre-vegetated. Additionally, the thin mats are easily removable, making maintenance and any necessary repairs to the roof easy.

Pathway

The main elements to consider when installing a pathway on a rooftop are the safety, maintenance, durability, and in our case, the weight of the walkway. To satisfy these elements, we recommend using a material called Thermoplastic Polyolefin (TPO) walkway pads (Versico, 2012). TPO walkway pads are specifically designed to protect roofing membranes in areas that receive heavy foot traffic. They provide the benefits of a slip-resistant material and the edges of the walkways are colored yellow to distinguish the path (Versico, 2012). The walkway pads are sold in 34" wide x 50' long rolls and the overall weight of these rolls is 88 lbs., which means the walkway weighs less than a pound per square foot (Versico, 2012). This is exceptionally lower than the weight of more commonly used green roof walkway material, such as stone and gravel. These walkways are easily installed by welding all four sides of the walkway to the roofing membrane (Versico, 2012). The pads are also available in the color white, which will help increase the reflectivity and insulation of the rooftop (Versico, 2012). Additionally, there is the option to purchase an improved weathering package to ensure long-term performance (Versico, 2012). These qualities make the material a perfect match for a long-term green roof that needs to be resistant to harsh weather conditions and high quantities of ultraviolet exposure. Overall, these walkway pads seem to be one of the best options for introducing a cost and weight effective pathway on our roof garden design.

Observation Deck

To allow people to view the wetlands roof garden without actually stepping onto the roof garden, an observation deck could be built directly adjacent to the south side of the Heffner Wetlands Building. Building an observation deck adjacent to the wetlands roof garden would provide numerous benefits. An observation deck would eliminate foot traffic from tourists and spectators on the roof garden, meaning the Heffner Building would bear much less weight from roof access. The only people that would actually need to walk on the roof garden would be the individuals maintaining the roof garden or using the roof garden for its research benefits. Eliminating roof garden access to the general public greatly reduces the live load that the Heffner Wetlands Building must bear.

Additional benefits of building an observation deck adjacent to the Heffner Wetlands Building's Roof, besides reducing the amount of weight that the roof must hold, are that the observation deck would create a unique vantage point of the surrounding wetlands, it could be fitted with tables and educational signage, and it would provide an access point to the roof garden for maintenance and research. A new roof-side observation deck would provide a unique vantage point by giving a second-story bird's eye view of the landscape east of the Heffner building. We recommend an observation deck have picnic tables to encourage people to enjoy the roof garden and surrounding wetlands, and we recommend that it have educational signage to inform people of the different species common to the roof garden and surrounding wetlands. A six-foot picnic table weighs about 160 – 180 lbs. and would cost about $80 - $200 (*Lowe's*, 2013). Adding two or three picnic tables to the observation deck would be an easy and inexpensive way to encourage people to view the roof garden on the Heffner building. A final benefit of an observation deck is that we recommend the observation deck have an exterior staircase to allow access to the roof garden for maintenance and research. An exterior staircase is important because there is currently no roof access to the Heffner Wetlands Building. We recommend the staircase be fitted with a locking security gate to prevent people from accessing the observation deck and roof garden at night. The size of the observation deck would depend largely on price and available space. The price of a second story deck ranges from about $10 - $25 per square foot, plus labor cost ("Second Story Deck," 2013). To build an observation deck large enough to hold multiple people, along with picnic tables for seating, would be expensive, probably between $2,500 and $9,000, but this is substantially less expensive than the cost to completely rebuild the Heffner Wetlands Building so that it can hold the full weight of a roof garden and the live load of visitors. The observation deck would also need to meet specific design codes, such as having a railing that is at least three feet tall, which would add additional cost and labor.

Figure 2: Close-up of proposed observation desk design

Habitat Enhancement

As part of the wildlife attractors on the roof, there will also be bird baths, porous rain catching stones, and native bee boxes near the viewing platform. These additions will provide drinking water for birds and pollinators, bathing water for birds, and shelter for native bees.

These will also be a great learning tool to educate students and visitors on how to care for wildlife and provide native species with the habitat components that they need to thrive.

The bee boxes will be constructed from the same plastic lumber as the raised beds. The lumber will form a 2ft. x 2ft. vertical frame placed on a support pole and filled with the hollow stems of reed grass (Shepherd, 2012). The stems will provide nesting structure for native bees and will enhance the numbers and diversity of species that can be viewed from the platform (Shepherd, 2012). The bird baths will be 1.5" deep, 5' wide pools of water and will be supplied with rainwater runoff from the roof. Large flat stones with porous indents will be placed near the platform to catch rainwater and form small puddles for insects to drink out of.

With nectar producing plants, a source of water, and shelter for native bees, there would be plenty to see near the platform and many learning opportunities to educate people on native species conservation and diversity.

Additional Space

Our proposed design also leaves some open space available that can either be left alone or used for future proposed projects. This section of the rooftop is less structurally viable for heavy projects, so weight would have to be taken into consideration. If possible, we recommend the installation of solar panels upon this space. This would prove beneficial to the overall structure, because solar panels work most efficiently when paired alongside or upon green roofs (Weaver, 2012). The cooling effect provided by roof gardens allow photovoltaic panels to perform at optimal performance levels, instead of overheating like they normally do on a blacktop roof (Weaver, 2012). Additionally, the plants help reduce the amount of pollutants and dust particles that could interfere with the productivity of the panels (Weaver, 2012). Studies have shown that this can boost efficiency by 3% to 16%, which would greatly complement the green roof's ability to increase energy savings (Weaver, 2012).

Maintenance

The maintenance of gardens has many hands-on educational advantages and benefits (National Wildlife Federation, n.d.). There is a relatively strong presence of student organizations with environmental focuses that are already involved in the maintenance of natural habitats in and around campus. These organizations, based on precedent, would be willing to take care of such a garden. A more concrete plan for maintenance would be to create an internship position at the Heffner building that would be in charge of roof maintenance and tours, harnessing work force that could either be free or relatively low-cost. This position could be provided at no charge through OSU's work-study program. Another option would be to arrange a deal with the Friends of the Chadwick Arboretum, volunteers who currently maintain the roof garden at Howlett Hall. Given the futuristic nature of our proposal these are the people and groups who we can only predict would be involved with the garden in the future. The current Student Farm Manager has assured us that this project would be in line with the OSU Student Farm mission and the Student Farm would welcome the opportunity to host and intern in the future if this project were to take place(Walter, 2013)

This would provide opportunities for volunteers, student workers, and researchers to get up close and personal with the plant life and wildlife of the roof garden. Typical maintenance of the roof garden would include:

- repairing and maintaining the structure of the raised beds
- hand removal of unwanted and invasive plant species
- possible removal of unwanted animal species
- pruning plants along the edges of the beds to prevent overgrowth
- maintaining and updating signage
- maintaining water catchment and irrigation systems
- maintaining potting media qualities and fertility
- replanting if necessary
- basic janitorial tasks
- ordering supplies and maintain budget

Other duties could include scheduling and giving educational tours from the platform and recording biodiversity by conducting species identification and monitoring.

Through these engagement opportunities, a student worker or community volunteer could play a large part in the roof garden project and receive a unique hands-on learning experience in roof garden maintenance, biodiversity conservation, and habitat management.

Educational Benefits/Opportunities

If we are indeed able to implement such an environment, then this roof garden will allow for unprecedented educational opportunities at OSU. A green roof offers a myriad of social benefits, but perhaps the most compelling argument for the installation of a roof garden on the Heffner Wetland Research Building is the increase in space for research, as well as simply an exposure of students and community members to the ecosystem services that Wetlands have to offer. A roof garden would also foster community development, provide health benefits to visitors/employees, and provide an aesthetically pleasing outlet for community members to socialize.

We chose to focus our green roof on increasing local wildlife vitality by planting vegetation that would attract native air-borne species. This aspect of our roof garden allows students and surrounding community members access to a unique location to congregate while being immersed in local flora and fauna. We hope such direct contact with this native eco-system will foster an appreciation for the natural world. As one of the largest universities in the nation, the Ohio State University carries a responsibility to not only build a greener campus, but also prepare a generation of educated youth that feel duty-bound to lead the way in making the necessary changes in order to sustain life in the wake of contemporary environmental issues. In order to accomplish this, OSU must not only incorporate sustainability into its curriculums, but also provide students with opportunities for hands-on service learning pertaining to conservation.

To instill a value of ecosystem services in individuals, a transformative learning approach must be taken. Going beyond the acquisition of knowledge, transformative learning is the process through which an individual's perception of a topic is altered through personal experience coupled with critical thought (Louie-Badua and Wolf, 2008). Keeping this in mind, one can also consider the innate spiritual link that humans feel with nature. If OSU is able to unlock this treasure trove of transcendent connection that rests dormant within some, then it may be able to succeed in putting forth graduates who carry this with them for the rest of their lives—influencing future policy and business practices, as well as achieving lifestyle changes that are able reduce the human carbon footprint. Service learning forges a bond between inner thoughts and subsequent actions as well as develops a sense of community, molding an individual whose inner convictions inspire a lifetime commitment to serving that which gives him purpose (Louie-Badua and Wolf, 2008).

Essentially, through the provision of hands-on experiences for students to connect with the natural world, OSU will be able to achieve this goal of increasing ecological awareness and appreciation among its students. This is a two-step process. The first of which would be to create opportunities for students to get involved in conservation projects, both on and off campus. This is where the roof garden comes in, creating a golden opportunity for students to be exposed to a valuable and natural resource right on OSU's campus. Student involvement can be manifested in a variety of ways, ranging from volunteer maintenance to research prospects to simply familiarizing oneself with local wildlife. Not only do we hope that this green roof will be integrated with student life, but also increase student awareness of such a unique resource at the Scheirmeier Wetlands. This roof garden can act as a catalyst that piques students' interest in the wetlands and motivates them to look into other ways to get involved both there and around campus.

The second part of this plan is to reintroduce the wetlands to campus in such a way that will grab students' attention and increase traffic in the area. In order to achieve this, certain marketing strategies may be useful. Since the wetlands are located somewhat out of the way of central campus, they fall prey to the "out of sight, out of mind" mentality. To add another layer of difficulty, those attempting to increase student enthusiasm for the wetlands may be met with some level of apathy from students who feel disconnected from the environment. If one wants to change consumer behavior, one must attempt to alter consumers' beliefs, which in turn affects their attitude (Perner, 2010). The best bet to increase student involvement at the wetlands is through the *mere exposure* effect: the idea that simply bombarding consumers with advertisements of a product increases likeability, even if beliefs stay the same (Perner, 2010). Although augmenting student awareness of the importance of conservation is the end goal, it is more important to draw students out to the wetlands and greater attention to sustainability will follow.

There are a few different media outlets available at OSU that would be able to showcase the wetlands. There are at least 3 student newspapers, The Lantern, UWeekly, and The Pulse, that could be contacted about writing a piece on the construction of a green roof on the Heffner building. Beyond student newspapers, the Columbus Dispatch could be approached as well in an effort to proliferate the surrounding community's involvement. Resident TV stations are also sources of local journalism that could follow the green roof's progress and would be able to reach large volumes of community members. Yet another way that developments at the wetlands could be tracked is by heavily featuring the Heffner building on OSU's website. This would be able to garner constant attention from OSU students and faculty, really milking the mere exposure effect. Moreover, further publicity could be gained by placing advertisements for the wetlands in the CABS busses, again applying the mere exposure effect to permeate students' minds (Perner, 2010).

Not only would a roof garden be emotionally fulfilling for students, it would also provides an unparalleled opportunity for students and faculty to conduct research. Such an enclosed area would allow researchers to closely monitor and observe plant, animal, and insect behavior in the wetland environment. Especially with our focus on the attraction of airborne species, this green roof would serve as an enclosed environment for researchers from several fields, such as the entomology, horticulture, and biology departments at OSU. It would also serve as an introduction to the native wildlife prevalent in the Olentangy Wetlands, beneficial to college students who are unaware of the ecology surrounding their own university, as well as K-12 student groups who come to tour the wetlands. Perhaps most importantly, a roof garden on top of the Heffner building would give unprecedented opportunity to conduct research on green roofs themselves, a relatively new field, putting Ohio State ahead of the curve yet again.

There is also evidence of a correlation between human interaction with the outdoors and an increase in human health. Frederick Law Olmsted once said, “Humans have physiological reactions to natural beauty and diversity, to the shapes and colors of nature, especially to green, and to the motions and sounds of animals” (Macdonagh, 2008). According to a study of post-surgery patients in recovery at a Texan hospital, patients with exposure to green space recovered quicker with less chance of relapse than those who did not (Pineo and Barton, 2009). Providing a green roof garden could augment interaction with the wetland wildlife, resulting in more active, healthier lifestyles for those exposed. It has also been shown that exposure to natural spaces can increase productivity in the workplace. According to “Benefits of Green Roofs” by L. Peter MacDonagh, a year after a green roof was installed on the roof of the Gap headquarters absenteeism decreased while productivity increased (Living Roofs). If the roof garden is able to be marketed successfully, and results in greater student outreach, OSU students and staff would be able to reap the benefits of a stronger connection with the environment.

Economic Benefits

Installing a roof garden on the Wetlands Research Facility will undoubtedly be expensive, but the cost of a roof garden can easily be justified. A roof garden on the WetlandsResearch Facility could provide numerous economic benefits that would help rationalize the initial installation fee. An organization, class, or new employment position could be created to provide inexpensive maintenance of a roof garden on the Wetlands Research Facility. Other than maintenance of vegetation, a roof garden on the Wetlands Research Facility would only require maintenance of the roof systems every decade or so. Most of the installation cost of a roof garden on the Wetlands Research Facility would be recovered through economic benefits within 25 to 35 years. Economic benefits that would stem from the installation of a roof garden on the Wetlands Research Facility include increased insulation and increased roof life longevity.

Insulation

The Wetlands Research Facility is a very poorly insulated building, which is one of the reasons it is such a perfect candidate for a retrofitted green roof. Installing a roof garden on the Wetlands Research Facility would add an extra layer of insulation that would help to keep the building warm in the winter and cool in the summer. The introduction of a roof garden could reduce air-conditioning energy by 25% to 80% in the summer (Saadatian, 2013). The Wetlands Research Facility has a poor air conditioning system, so installing a roof garden to the building would greatly reduce the need for air-conditioning. An extensive layer of Xero Flor and insulated walkways would be expected to provide about a 25% reduction of air-conditioning energy, and areas with intensive raised beds would be expected to provide even greater insulation efficiency.

Retrofitting roofs with green roofs can help insulate buildings with the benefits of saving energy and saving money. The soil medium and foliage of roof gardens absorb heat energy from the sun, reducing the temperature of the building (Clark, 2008). A roof garden on the Wetlands Research Facility would help to reduce air temperature and air humidity in the building because the vegetation would absorb heat and moisture, while a wet soil medium would insulate against heat. Most research on insulation benefits of roof gardens only accounts for the summer season and often overestimates the insulation benefits (Sailor, 2008). Although most research overestimates insulation benefits from green roofs, the roof garden on the Wetlands Research Facility could be expected to have a high insulation efficiency increase, because the building is currently poorly insulated; also the building is in a region with very cold winters, very hot summers, and high humidity year round.

Roof Life

The installation of a green roof on the Wetlands Research Facility could greatly increase the roof life of the building. The soil medium required for vegetation on a roof garden creates an extra layer of protection for the roof membrane. The soil medium of roof gardens protects the roof membrane from excessive heat, excessive exposure to light, precipitation, wind, and other weather conditions such as hail. Since conventional roofs do not have a soil medium protecting them from the sun and weather, they often need maintenance or replacement of the roof membrane more frequently than green roofs. Conventional roofs generally require system replacements every 10 – 15 years, whereas green roofs usually require system replacements every 45 – 50 years (Kosareo, 2007). The Wetlands Research Facility's current roof is very thin and outdated, requiring system maintenance every decade or so, but if a retrofitted roof garden were installed on the building then the soil medium would help protect the roof system from exposure to the sun and weather and the roof would only require system maintenance once every 25 – 45 years. Installing a roof garden on the Wetlands Research Facility would potentially increase the time between roof system maintenance, and roof replacement, by two to three times. A roof garden on the Wetlands Research Facility would require some regular maintenance (such as pruning of plants and weeding gardens), but regular maintenance would be minimal. With the savings in insulation cost and the increased roof life longevity, a retrofitted roof garden would be expected to pay for itself in less than 40 years (Clark, 2008). Additionally, with the Wetlands Research Facility's roof being outdated and the building being poorly insulated, a retrofitted roof garden on the Wetlands Research Facility would be expected to pay for itself in 25 to 35 years.

Although installing a roof garden on the Wetlands Research Facility would be expensive, the green roof would be expected to pay for itself through savings in insulation and roof life longevity. It is understandable that funders of the Wetland Research Facility would still be hesitant to install a green roof because of the large price tag. Since the Wetlands Research Facility will need to have heavy maintenance done on its roof (or even have its roof replaced) in the next 5 to 10 years, it may make more sense to install a green roof while the roof is already being renovated. This would eliminate the need to reconstruct the entire roof, because modifications to the roof that need to be made for the garden could simply be added to the renovations of the existing roof. By waiting to retrofit the roof garden, unnecessary construction, costs, and modifications to the roof can be avoided.

Environmental Benefits

A roof garden on the Heffner Wetland Building has the potential to provide many environmental benefits to the biological diversity of the Olentangy River Wetland Research Park. With the roof being elevated above the surrounding landscape, and with the chance to grow native flowering plants, there is the opportunity to provide many of the ecological benefits associated with an upland prairie ecosystem. These include nectar and pollen sources for pollinators, seeds for birds, and shelter for these native species. Other benefits include reduced rainwater runoff and increased carbon sequestration. These, along with many other benefits provide a multitude of reasons as to why we are proposing the construction of a roof garden featuring an upland prairie ecosystem at the Wetland Research Park.

The conservation and enhancement of biological diversity is a major initiative of the environmental movement and it was also an important aspect of the purpose behind the development of the Olentangy River Wetland Research Park. Designing a roof garden at the facility that will grow native prairie flowers has the potential to provide additional ecosystem enhancement to the already established wetlands on site by modeling an upland prairie. There are dozens of native prairie flowers that grow in the Midwest that are typically very hearty and drought tolerant (Lady Bird Johnson Wildflower Center, 2013). These features make them ideal for roof gardens.

Not only are native prairie flower species an important part of biodiversity conservation, but they also provide nectar and pollen for a wide variety of pollinator species (Borgmann & Rodewald, 2002). Insects are an extremely diverse group of mostly terrestrial arthropods with many flying insects that depend on flower nectar and/or pollen as a food source. These insects include, but are not limited to, bees, wasps, beetles, butterflies, moths, and predatory flies (Rodewald, 2001). Other pollinators, like hummingbirds, also benefit from nectar producing flowers (Rodewald, 2001). Some native plants, such as Canada thistle and sunflower, produce seeds which many native bird species readily feed on (Rodewald, 2001). Finches, woodpeckers, and an abundance of other perching bird species rely on seeds as a major component of their diet and growing these seed bearing plants will provide an additional source of food for the wetland's birds (Rodewald, 2001). Different plants flower and produce seeds at different times of the year, so the careful selection of a wide variety of native plants will ensure an almost year-round supply of nectar, pollen, and seeds (Borgmann & Rodewald, 2002). Some insects, such as aphids and leaf hoppers, feed on plant sap and others like grasshoppers feed directly on the vegetation. In turn, there are many other insects and birds that feed on these nectar and plant feeding insects, which means multiple trophic levels at the wetlands would benefit from a prairie flower roof garden.

Plants do much more than just supply food for pollinators and birds. They also help to sequester carbon, slow down and utilize runoff water, and provide shelter for wildlife. Many insects and ground nesting birds rely on prairie vegetation for protection from rain, shelter, and structural support for nests (Rodewald, 2001). The plants that will be selected for the roof garden design will exhibit these beneficial traits.

While the roof garden will be planted with many native prairie flowers, it will also exhibit other features that will further enhance its environmental and ecological benefits. Features such as bee boxes will be placed on the roof to provide a highly efficient, manmade source of nesting shelter for native bees. Native bee conservation is a component of the broader pollinator and invertebrate conservation movements (Shepherd, 2012). This would be a specialized and important aspect of the purpose for designing and building this roof garden. Another addition to the roof that would enhance its ecological benefits would be the placement of porous stones to catch rainwater and form small pools for insects to drink (Borgmann and Rodewald, 2002). Bird baths would also do the same for native birds, as well as provide them with a way to clean themselves.

The environmental and ecological benefits of having a roof garden at the wetlands are both wide ranging, and in terms of biodiversity, substantial. While the wetlands have focused much on vertebrate conservation, this is an opportunity to conserve birdlife while also considering the needs of smaller invertebrates and enhancing their biodiversity and numbers. Though it will be manmade, having a "prairie ecosystem" within the Wetland Park would create a more diverse ecosystem that can support more wildlife than the park was previously capable of both in terms of wildlife populations and diversity. This is an opportunity for the Wetland Research Park to grow its conservation efforts and provide other benefits to the environment around the Heffner Building and throughout the park. It will hopefully provide a model for other sustainability and conservation efforts across the OSU campus, as well as other institutions and municipalities.

Discussion

We are proposing a long term project whose benefits are far-reaching for Ohio State's reputation, its impact on the environment and its students. Since the roof will have to be reinforced in order to be able to support a green roof, this venture will require an initial investment that may seem daunting; we address this issue by recommending the most cost and weight effective materials we could find. By reducing the amount of weight the roof will have to hold, we minimize the amount of reconstruction that will have to be done. We also recommend timing the retrofit of the roof with the already scheduled projected maintenance within the next ten years thus making this renovation as efficient as possible.

If at first we envisioned an extensive roof garden area that would be available for unlimited access by students and community members, we have adapted our plans in order to comply with the limits on the amount of weight the Heffner Building is able to hold. We found innovative lightweight material such as perlite and Xero Flor, and we have since shifted our vision from an all-access, extensive roof garden to a limited access, mixed intensive/extensive garden with an adjacent observation deck that will provide the sort of congregational area that had at first been intended for the roof itself. We believe, however, it is very important to rebuild the roof in such a way that it will be able to hold small groups (2-3 people). This will not only allow for maintenance to be performed but also will ensure that research will still be able to be conducted—one of the most exciting aspects of building a green roof at the Wetlands.

We are proposing a project whose economic and social returns are in compliance with OSU's effort to constantly progress as a university. A roof garden atop the Heffner building offers insulation benefits and increases roof life longevity. As a national leader, Ohio State has a stake in constructing buildings that are both cost-effective and environmentally friendly. OSU also has an interest in providing students with an area to both connect with the natural world and conduct the sort of ground-breaking research that makes Ohio State such a great school.

In addition to the already existing roof garden at Howlett Hall, building yet another green roof on OSU's campus sends a strong message of a commitment to environmentalism. If our proposal is carried out, observation over time of both the Heffner building and Howlett hall roof gardens will hopefully demonstrate the rich educational and economical returns that green roofs can offer. If indeed successful, one can anticipate that such projects would resonate across the community and campus as more buildings spring for the same kind of reconstruction, as well as push Ohio State administrators to plan for roof gardens from the very beginning stages of building construction. Not only could this make Ohio State's campus a beacon of sustainability efforts, it could also apply pressure on peer universities to follow the lead.

Conclusion

The construction of a green roof atop the Heffner building in the Schiermeier Wetlands Research Center would provide a plethora of benefits to the building itself, the whole of OSU's campus, and the surrounding community. Because reinforcement of the building structure would be necessary in order for the Heffner building to hold such a venture, we propose that the reconstruction be incorporated into the inevitable future renovations of the roof. Although increased expenditure would be required, the construction of a green roof is justified through the prospect of decreased energy costs and greater roof longevity. It also exhibits OSU's pledge to be a hub of sustainability through the provision of greater research opportunities within the wetlands. We've created a design plan that stays weight-conscious by using lightweight materials such as perlite and Xero Flor, as well as positioning our heaviest items over the most structurally sound areas of the roof. Another way to reduce the amount of weight that the roof will have to hold is the addition of a viewing deck built directly adjacent to the building.

Due to the long term nature of the project, there are certain issues to bear in mind, one of these being the responsibility of maintenance. Although no group has formally committed itself to the endeavor, there are a variety of options available. An internship position could be created that included tasks such as weeding flower beds and monitoring invasive species. There are also many environmentally motivated student organizations on campus that, based on precedent, would be interested in volunteering. Another concern is that because this project has such a long, projected timeline there is a possibility that it will fall by the wayside due to lack of interest or awareness among students. We hope that faculty enthusiasm can spearhead this project and ensure its completion even after those that proposed it have graduated. Ohio State holds a unique position of influence both nationally and globally; the social implications of committing to build another green roof on campus would only be in alignment with OSU's image as an ecologically-conscious institution.

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Appendix A

The following is a list of native Ohio prairie flowers that are drought tolerant and would be well suited for the roof garden. All of these species are flowering, herbaceous perennials that do well in full sunlight conditions (Lady Bird Johnson Wildflower Center, 2013). A wide selection of flowering plants would ensure that the pollinators had a reliable source of nectar for much of the year. Creating a diverse planting environment would also be a major component of the educational aspect of the project, which would be to teach people about plants that benefit native wildlife.

Prairie Flower Species:

Aromatic aster (Symphyotrichum oblongifolium)
Beach strawberry (Fragaria chiloensis)
Bigleaf aster (Eurybia macrophylla)
Blazing star (Liatris squarrosa)
Bluebell bellflower (Campanula rotundifolia)
Boltonia (Boltonia asteroides)
Browneyed Susan (Rudbeckia triloba)
Bull's coraldrops (Besseya bullii)
Butterflyweed (Asclepias tuberosa)
Canada goldenrod (Solidago canadensis)
Canadian milkvetch (Astragalus canadensis)
Canadian pussytoes (Antennaria howellii ssp. canadensis)
Candle anemone (Anemone cylindrica)
Common goldstar (Hypoxis hirsuta)
Common yarrow (Achillea millefolium)
Common yellow oxalis (Oxalis stricta)
Compassplant (Silphium laciniatum)
Creeping Phlox (Phlox subulata)
Cup plant (Silphium perfoliatum)
Dewberry (Rubus trivialis)
Dotted blazing star (Liatris punctata)
Downy gentian (Gentiana puberulenta)
Downy phlox (Phlox pilosa)
Dwarf red blackberry (Rubus pubescens)
Early goldenrod (Solidago juncea)
Eastern purple coneflower (Echinacea purpurea)
Elmleaf goldenrod (Solidago ulmifolia)
Fewleaf sunflower (Helianthus occidentalis)
Field pussytoes (Antennaria neglecta)
Flowering spurge (Euphorbia corollata)

Goat's rue (Tephrosia virginiana)
Gray goldenrod (Solidago nemoralis)
Greater tickseed (Coreopsis major)
Green milkweed (Asclepias viridiflora)
Hairy beardtongue (Penstemon hirsutus)
Heartleaf four o'clock (Mirabilis nyctaginea)
Hoary mountain mint (Pycnanthemum incanum)
Hoary puccoon (Lithospermum canescens)
Hoary skullcap (Scutellaria incana)
Howell's pussytoes (Antennaria howellii ssp. neodioica)
Jerusalem artichoke (Helianthus tuberosus)
Lanceleaf coreopsis (Coreopsis lanceolata)
Longleaf summer bluet (Houstonia longifolia)
Lyreleaf sage (Salvia lyrata)
Maximilian sunflower (Helianthus maximiliani)
Mexican hat (Ratibida columnifera)
Mississippi penstemon (Penstemon digitalis)
Narrowleaf evening-primrose (Oenothera fruticosa ssp. glauca)
Narrowleaf mountain mint (Pycnanthemum tenuifolium)
Narrowleaf silkgrass (Pityopsis graminifolia var. graminifolia)
Ontario blazing star (Liatris cylindracea)
Paleleaf woodland sunflower (Helianthus strumosus)
Palespike lobelia (Lobelia spicata)
Parlin's pussytoes (Antennaria parlinii ssp. parlinii)
Parlin's pussytoes (Antennaria parlinii)
Pink evening primrose (Oenothera speciosa)
Pinnate prairie coneflower (Ratibida pinnata)
Pitcher sage (Salvia azurea var. grandiflora)
Plantain-leaf Pussytoes (Antennaria plantaginifolia)
Prairie blazing star (Liatris pycnostachya)
Prairie goldenrod (Oligoneuron album)
Roundhead lespedeza (Lespedeza capitata)
Scarlet Sage (Salvia coccinea)
Showy tick trefoil (Desmodium canadense)
Silverleaf nightshade (Solanum elaeagnifolium)
Skyblue aster (Symphyotrichum oolentangiense)
Small pussytoes (Antennaria howellii ssp. petaloidea)
Smooth blue aster (Symphyotrichum laeve var. laeve)
Spreading dogbane (Apocynum androsaemifolium
Stiff goldenrod (Oligoneuron rigidum var. rigidum)
Strict blue-eyed grass (Sisyrinchium montanum)
Sundial lupine (Lupinus perennis)
Tall blazing star (Liatris aspera)
Tall thimbleweed (Anemone virginiana)
Virginia spiderwort (Tradescantia virginiana)
Virginia strawberry (Fragaria virginiana)

Western pearly everlasting (Anaphalis margaritacea)
Western silver aster (Symphyotrichum sericeum)
White colicroot (Aletris farinosa)
White heath aster (Symphyotrichum ericoides var. ericoides)
White snakeroot (Ageratina altissima)
White wild indigo (Baptisia alba)
Whorled milkweed (Asclepias verticillata)
Wild bergamot (Monarda fistulosa)
Wild foxglove (Penstemon cobaea)
Wood lily (Lilium philadelphicum)
Woodland flax (Linum virginianum)
Wreath goldenrod (Solidago caesia)

Appendix B

The following is a list of some of the native, pollinator species and taxonomic groups that would be attracted to the native flowering plants of the roof garden (ODNR). Pollinator conservation and diversity would be the major component of the educational material taught through this living laboratory.

Hummingbirds:
Calliope hummingbird (*Selasphorus calliope*)
Rufous hummingbird (*Selasphorus rufus*)
Ruby-throated hummingbird (Archilochu scolubris)

Butterflies and Skippers**:**
American Copper (*Lycaena phlaeas*)
American Painted Lady (*Vanessa virginiensis*)
American Snout (*Libytheana carinenta*)
Baltimore Checkerspot (*Euphydryas phaeton*)
Banded Hairstreak (*Satyrium calanus*)
Black Swallowtail (*Papilio polyxenes*)
Bronze Copper (*Lycaena hyllus*)
Cabbage White (*Pieris rapae*)
Clouded Sulphur (*Colias philodice*)
Common Buckeye (*Junonia coenia*)
Common Sooty Wing (*Pholisora Catullus*)
Common Wood Nymph (*Cercyonis pegala*)
Coral Hairstreak (*Satyrium titus*)
Eastern Comma (*Polygonia comma*)
Eastern Tailed Blue (*Everes comyntas*)
Eastern Tiger Swallowtail (*Papilio glaucus*)
Edward's Hairstreak (*Satyrium edwardsii*)
European Skipper (*Thymelicus lineola*)
Frosted Elfin (*Incisalia irus*)
Giant Swallowtail (*Papilio cresphontes*)

Gray Hairstreak (*Strymon melinus*)
Great Spangled Fritillary (*Speyeria Cybele*)
Grizzled Skipper (*Pyrgus cantaureae wyandot*)
Hackberry (*Asterocampa celtis*)
Harvester (*Feniseca tarquinius*)
Karner Blue (*Lycaeides melissa samuelis*)
Little Wood-satyr (*Megisto cymela*)
Meadow Fritillary (*Boloria Bellona*)
Monarch (*Danaus plexippus*)
Mourning Cloak (*Nymphalis antiopa*)
Orange Sulphur (*Colias eurytheme*)
Pearl Crescent (*Phyciodes tharpos*)
Peck's Skipper (*Polites peckius*)
Persius Duskywing (*Erynnis persius*)
Purplish Copper (*Lycaena helloides*)
Question Mark (*Polygonia interrogationis*)
Red Admiral (*Vanessa atalanta*)
Red-spotted Purple (*Limenitis arthemis*)
Silver-spotted Skipper (*Epargyreus clarus*)
Spicebush Swallowtail (*Papilio Troilus*)
Spring Azure (*Celastrina ladon*)
Summer Azure (*Celastrina neglecta*)
Viceroy (*Limenitis archippus*)
Zebra Swallowtail (*Eurytides Marcellus)*

<u>Common Bee Species and Major Groups:</u>
Bumble bee (Bombus spp.)
Leaf cutting bee (Megachile spp.)
Large Carpenter bee (Xylocopa spp.)
Mason bee (Osmia spp.)
Squash bee (Peponapis pruinosa)
Small carpenter bee (Ceratina spp.)
Mining bee (Andrena spp.)
Long horned bee (Melissodes spp.)
Sweat bee (Halictidae spp.)
Pileated woodpecker *Dryocopus pileatus*
Red-bellied woodpecker *Melanerpes carolinus*

Appendix C

By planting large, seed producing sunflowers (*Helianthus annuus*) and Canada thistle (*Cirsium arvense*), the following native bird species would be expected to frequent the roof garden for feeding purposes (ODNR).

<u>Seed Eating Bird Species</u>**:**
Downy woodpecker (*Picoides pubescens*)

Blue jay (*Cyanocitta cristata*)
Black-capped chickadee (*Poecile atricapillus*)
Carolina chickadee (*Poecile carolinensis*)
Tufted titmouse (*Baeolophus bicolor*)
White-breasted nuthatch (*Sitta carolinensis*)
Red-breasted nuthatch (*Sitta Canadensis*)
Red-winged blackbird (*Agelaius phoeniceus*)
Common grackle (*Quiscalus quiscula*)
Northern cardinal (*Cardinalis cardinalis*)
Evening grosbeak (*Coccothraustes vespertinus*)
Purple finch *Haemorhous purpureus*
Common redpoll *Carduelis flammea*
Hoary redpoll *Carduelis hornemanni*
Pine siskin *Carduelis pinus*
American goldfinch *Carduelis tristis*
Dark-eyed junco *Junco hyemalis*
Tree sparrow *Passer montanus*
White-throated sparrow *Zonotrichia albicollis*
White-crowned sparrow *Zonotrichia leucophrys*
Song sparrow *Melospiza melodia*